A habitat-based framework to predict the effects of agricultural drain maintenance on imperiled fishes

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ABSTRACT

One third of the total global land viable for agricultural production has artificial drainage systems. These drainage systems can provide important habitat for fishes and, in some cases, imperiled fish species vulnerable to impact by drainage maintenance activities. A framework to provide quantitative assessments of the effects of maintenance activities on imperiled fish species is needed. In this study, a six-step habitat-based framework was developed to predict suitable habitat for two at-risk species in an agricultural drain: the Endangered Pugnose Shiner (Notropis anogenus) and the Special Concern Blackstripe Topminnow (Fundulus notatus). Using the framework, spatial models were developed to assess the effects of proposed drain maintenance on the overall amount of suitable habitat, habitat patch size, and connectivity of habitat patches. Maintenance had a significant impact on habitat connectivity, but did not significantly reduce the habitat size of isolated patches. Maintenance had a significant impact on habitat connectivity, but did not significantly reduce the habitat size of isolated patches. The amount of suitable habitat available after maintenance fell below the minimum area for population viability (MAPV) for the Pugnose Shiner, but not the Blackstripe Topminnow. Future impact assessments of drain maintenance should incorporate population viability analysis, coupled with habitat patch analysis (patch size and connectivity), to quantitatively test consequences of proposed alteration to the viability of spatially structured populations.

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1. Introduction

Agricultural intensification has resulted in both direct and indirect negative impacts on biodiversity (Pimm and Raven, 2000; Sala et al., 2000; Billeter et al., 2007; Blann et al., 2009) and has caused widespread loss and degradation of natural ecosystems (Sala et al., 2000; Tilman et al., 2001; Pereira et al., 2010). Nearly 40% of global land cover is occupied by cropland and pastures (Foley et al., 2005), of which one third has been altered to improve drainage (Smedema and Ochs, 1997). Subsequently, there has been a considerable loss of wetland habitat associated with agricultural land use (Blann et al., 2009). Wetland loss is accompanied by a reduction in important ecosystem functions (Zedler and Kercher, 2005), such as carbon sequestration (Post and Kwon, 1999), water-quality improvement (Foley et al., 2005), biodiversity support (Reidsma et al., 2006), and altered hydrology and nutrient cycles (Blann et al., 2009).

In Canada, 16 million ha of agricultural farmland have been artificially drained (Skaggs et al., 1994). The creation and modification of agricultural land in Canada has led to a considerable loss and fragmentation of wetland habitat, predominantly in the Great Lakes basin (Staton and Mandrak, 2006). In southwestern Ontario, the construction of agricultural drains has been responsible for 86% of all wetland loss (Ducks Unlimited Canada, 2010). Over the past century, wetland-dependent species in this region have faced significant threats from habitat alteration associated with agricultural practice (Stein and Flack, 1997; Walters and Shrubsbole, 2005; Mandrak and Cudmore, 2010). As in southwestern Ontario, agricultural drains can serve as remnant wetlands that support rich and diverse aquatic communities, in lieu of native wetland habitat (Williams et al., 2004; Stammerl et al., 2008; D’Ambrosio et al., 2014; DFO, 2015) including several wetland-dependent fish species at risk (Doka et al., 2006).

For fish species now dependent on these agricultural drainage systems, subsequent activities undertaken to maintain the function of drains can lead to a significant decline in population size or, more directly, local extirpation (Weller, 1981). Drain maintenance involves additional modification of channelized streams by removing...
substrate and vegetation from in-stream and riparian zones. Removal of in-stream habitat can reduce habitat quality, patch size, and patch connectivity (Ewers and Didham, 2006), which can have significant impacts on fish composition (Stauffer et al., 2000), in-stream habitat diversity (Jones et al., 1999), and regional fish population size (Hodgson et al., 2009). Loss of riparian vegetation can have a strong influence on in-stream water temperature, habitat, cover, and primary production (Gregory et al., 1991).

Management of agricultural drains requires consideration of the need to protect private property and public infrastructure from flooding, to maintain the productivity of agricultural lands, and to support important ecological values. To prevent the decline in aquatic ecological function, productivity, and biodiversity of drains, it is essential that the impacts of maintenance are better understood and effective mitigation strategies are developed. In Ontario, under an amended regulation of the Endangered Species Act (ESA), proponents are required to follow best management practices to minimize adverse effects of drain and ditch activities that may harm at risk species and their habitats (Environmental Commissioner of Ontario, 2013). The federal Species at Risk Act (SARA) requires permits for proposed maintenance or repair that may harm critical habitat (S.C. 2002, c. 29). Although often not legally binding, an environmental impact assessment (EIA) is considered a valuable tool for development assessment, planning, and management (Dougherty and Hall, 1995). Typically, an EIA of a planned drain maintenance project involves site-specific surveys to ensure that a proposed project is properly scoped and potential impacts are identified (Dougherty and Hall, 1995). However, no guidelines specific to the ‘Scoping’ and ‘Prediction and Mitigation’ steps exist to improve consistency and congruence among projects. Furthermore, few quantitative tools to assess the effects of drain maintenance on fishes and fish habitat exist (Spaling, 1995; Spaling and Smith, 1995). Predictive habitat-based models are required to identify the type, location, and quantity of habitat required to be protected from modification, so that drains can support viable fish populations. In other riverine systems, such habitat-based models have been useful to predict the responses of fishes and macro-invertebrates to restored flow conditions (Lamouroux et al., 1999; Mérigoux et al., 2009), and to reduce the harm of instream infrastructure projects to endangered fish (Roberts et al., 2016).

In our study, a habitat-based modelling approach was taken as part of a six-step framework to assess the effects of maintenance on freshwater fish species at risk in an agricultural drain, Little Bear Creek (Ontario, Canada). Predictive habitat-based models can be used to predict directly habitat, and indirectly species, responses to drain maintenance and mitigation. When coupled with spatially-explicit information on habitat characteristics along a study reach, habitat models provide a more flexible and comprehensive approach than impact assessments based only on locations where species have been detected. This is an especially important consideration when modelling impacts on endangered fishes, as these species are often difficult to detect during inventories (Bayley and Peterson, 2001) and interpretations of potential impacts may be biased due to non-detections (Guilleria-Arroita et al., 2015).

To evaluate the potential effects of drain maintenance, a vegetation model was developed to predict the distribution of two at-risk species and their suitable habitat in an agricultural drain: the Endangered Pugnose Shiner (Notropis mogenus) (COSEWIC, 2013) and the Special Concern Blackstripe Topminnow (Fundulus notatus) (COSEWIC, 2012). Pugnose Shiner and Blackstripe Topminnow are small-bodied fishes that prefer shallow, slow-moving waters with dense aquatic macrophytes (Edwards and Stanom, 2002; Fisheries and Oceans Canada, 2012; Gray et al., 2014; McCusker et al., 2015). For both species, the loss of in-stream and shoreline vegetation during drain maintenance is considered a substantial threat to population persistence (COSEWIC, 2012; Fisheries and Oceans Canada, 2012).

For small-bodied fishes with low dispersal ability, connectivity between habitat patches (in addition to patch size) also plays an essential role in population persistence (Levin et al., 2000; Hodgson et al., 2009). Connectivity is especially critical following disturbance events, when degraded populations are dependent on healthy, source populations for recovery (Mumbry and Hastings, 2008). Minimum area of population viability (MAPV), the amount of suitable habitat required to support a viable population (Vélez-Espino et al., 2010), can be used to interpret the sensitivity of fishes to changes in habitat size and connectivity following activities such as drain maintenance. In the last step of the six step framework, population-level impacts of drain maintenance were assessed by considering the effects of drain maintenance on MAPV based on: (1) overall habitat area, (2) abundance and size of habitat patches; and, (3) habitat connectivity (distance to the nearest patch).

2. Methods

2.1. Study area

Little Bear Creek is a tributary of Lake St. Clair located within the municipality of Chatham-Kent in southwestern Ontario (42.531239, –82.401805) (Fig. 1). Little Bear Creek drain was constructed prior to 1886 and has since undergone drain maintenance twice (1919 and 1972). The surrounding agricultural land drains into the low-gradient Little Bear Creek through subsurface pipes known as tile drains. Little Bear Creek reaches are transitional or stressed/instable, based on evidence of aggradation, degradation, and erosion in the form of widening and plan form adjustment (Urban Environmental Management Ltd., 2014). The study area spans the first 11 km (of 29.5 km total) upstream of the mouth at the Chenal Ecarte (Fig. 1). The channel width of the study site is 29.23 m on average, 42 m wide at the mouth, and 10 m wide at the farthest point upstream. The mean channel depth of the study site is 2 m deep at the mouth and 0.8 m at the furthest upstream point.

Little Bear Creek and its riparian zone are important habitat for a wide variety of species and proposed maintenance may negatively impact those species and/or their critical habitat. This includes at-risk species such as Blanding’s Turtle (Emydoidea blandingii), Canvasback (Aythya valisineria), and Eastern Prairie Fringed-orchid (Platanthera leucophaea) (Urban Environmental Management Ltd., 2014). Little Bear Creek also supports a diverse fish assemblage of 61 fish species, including species protected by the federal Fisheries Act and six species listed under the federal Species at Risk Act (Table 1), and is currently legally identified as critical habitat for the Pugnose Shiner (Fisheries and Oceans Canada, 2012). Therefore, there is concern regarding the potential impacts of drain maintenance on the aquatic community, including at-risk fishes. A six-step habitat-based framework was developed to assess the impacts of maintenance on Pugnose Shiner and Blackstripe Topminnow (Table 2).

2.2. Assessment framework

2.2.1. Conduct pre-maintenance community assessments

Fish data were collected to better understand the distribution and abundance of at-risk fish species in Little Bear Creek and to develop species-habitat relationships for Pugnose Shiner and Blackstripe Topminnow. Habitat model fish were developed using aquatic vegetation and channel bathymetry data. An aquatic vegetation survey of Little Bear Creek was conducted at 25 sites August 4–11, 2014 (Wiklund, 2015). Each site was divided into one...
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